RESEARCH ARTICLE

# Briquetting of Sesame Stalk using Waste Paper as Binding Agent to Replace Petcoke

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**ABSTRACT:** Investigation of the development and characterization of briquette from sesame stalk and waste paper as binder was examined for production of fuel briquettes. The raw sesame stalk was characterized by the following properties: moisture content (3.63%), fixed carbon (17.50%), volatile matter (72.82%) and ash content (6.05%). Briquettes were produced by mixing carbonized sesame stalk with waste paper in weight percentage ratios of 90:10, 80:20, 70:30, 60:40 and 50:50 at three different average particle sizes of sesame stalk (1, 3 and 5mm).From the experiment, the results of all sesame stalk briquettes fall in the range of bulk density (526.21-535.62Kg/m$^3$), shatter resistance (88.02-89.07%), volatile matter (64.01-69.20%), ash content (10.46-14.25%) and calorific value (25.167-28.00MJ/Kg). The combination of 5mm average particle size of sesame stalk and 10% waste paper percentage gave the optimal volatile matter of 69.20%, ash content 10.46% and calorific value 28.00MJ/kg. From the results of the present study, it may be concluded that calorific values of briquettes obtained were enough to produce energy content for combustion and due to this about 40% consumption of petcoke of Dashen cement factory with sesame stalk fuel briquette can reduce about 2,410 tons of $CO_2$ per year emitted from combustion of fossil fuel petcoke and that can affects the environment.

**KEYWORDS:** Sesame stalk, Waste paper, Briquettes, Petcoke

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## 1. INTRODUCTION

Increasing energy needs of the world has been alarmingly increased in the past century as the population of the world continues to grow. Energy resources are normally categorized as renewable and non-renewable. Renewable energy sources are considered a better alternative, environmentally friendly and are thus better candidates for use in getting some measures of technological development under a sustainable environment both in the developed and developing nations [1]. Among the various renewable energy sources biomass is widely accessible and some alternative biomass fuels have lower energy-specific $CO_2$ emissions than coal; others have higher emissions. Conventional or non-renewable sources of energy are very limited and depleting very rapidly. Biomass is any type of organic renewable materials which contain energy in a chemical form and converted to fuel, accordingly sesame stalk biomass briquetting is one of the important alternative sources of renewable energy.

In certain circumstances, be regarded as a net zero-emission fuel-source, even if $CO_2$ is liberated during its combustion. If biomass residues are cultivated sustainably and the rate of biomass extraction is not higher than the rate of biomass re-planting or replenishment then the biomass is considered to be 'carbon emission neutral'. The logic is that the biomass grown to replace the combusted biomass is considered to absorb $CO_2$ from the atmosphere while growing, thereby in effect 'cancelling out' the $CO_2$ emission associated with the combustion of the cultivated biomass: the net effect on the atmospheric carbon balance is zero. Sustainably-cultivated biomass has, in effect, an emission factor of zero. The uses of agricultural and agro-industrial waste biomass are organic mass fraction consists of cellulose, hemicelluloses, and lignin.

The common agricultural and industrial residues contain timbering residues; oilseeds shells such as groundnut, coffee husks, rice husks, cotton wastes, sugarcane bagasse [2]. But these large quantities of agricultural and forestry residues have not been so far utilized as expected [3]. From the different forms of biomass energy sources, sesame stalk is one of the significant sources of biomass renewable energy. Briquettes produced from lignocelluloses' waste, through a simple method and low cost are an excellent source of cheap energy and environmentally acceptable. Conventional fuels used in cement

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factories, such as coal, petcoke, and furnace oil, can be partially replaced by biomass fuels. Different plants can also benefit from added revenue from the Clean Development Mechanism (CDM), as biomass energy can decrease $CO_2$ emissions to a large extent[4].

This study is intended to produce fuel briquettes from sesame stalk using a binding agent and for replacement of fossil fuel in a cement kiln. The effect of operating parameters like the addition of binder and particle size on properties related to the heating value of fuel briquettes made from sesame stalk is determined. This study has also developed scientific procedures to generate smokeless renewable energy from the sesame stalk with a binding agent and the right proportion of binders to be used while producing. Energy use in Ethiopian cement industry is the process of clinker production in the pre-heaters / pre-calciners, and kilns are the particularly energy-dependent system. The usual fossil fuels used in the cement industry are coal, petcoke, heavy furnace oil and natural gas. Recently, there has been a trend to replace fossil fuels with alternative renewable fuels derived from industrial waste, urban waste, and biomass[5].

## 2. MATERIALS AND METHODS

Feedstock (sesame stalk) was collected from farmers in Kafta Humera which is the main source of sesame stalks in Ethiopia[6]. Locally available materials such as, waste paper and maize flour were collected for binding purpose. The sesame stalk was dried using Oven/ incubator, electrical furnace at more 30-3000$^0$C heat. Other materials like analytical balance (sensitive to 0.0001g), sieves (1mm, 3mm and 5mm mesh size), hammer mill and mixer (robot @ coupe, R23), manual briquetting press, crucibles, meter, desiccators, plastic basin, stove, and oxygen bomb calorimeter (Parr 6200) were the equipment's used to characterize sesame stalk and the briquettes during the analysis.

### *2.1 Briquetting production process*

In this study production of briquette from sesame stalk was planned to substitute for petcoke which is the main raw material for Dashen cement factory. The over all production process of sesame satlk follows the steps shown on Figure 1. During the production three steps were carried out. On the first step waste paper and sesame stalk were collected from the local source as raw material of the process. Then Physico-chemical properties of a raw sesame stalk were determined and carbonized sesame stalk was sampled and mixed with a binder[7]. Soaked waste paper and maize flour as a control were used as a binder during the production of sesame stalk briquettes[2]. Finally,analysis of physical and combustion properties of sesame stalk briquettes was done.

### *2.1 Raw material preparation for sesame stalk briquette*

The feedstock (sesame stalk) was collected from the local source and washed to remove dust, soil, stone, and other impurities and air dried to reduce moisture content. A portion of the dried sesame stalk was screened by standard mesh sizes less than 6mm which were arranged vertically starting from the smallest to the widest sieve size and mounted in an electrical sieve shaker[8]. Effect of particle size of sesame stalk was considered for briquetting purpose to see the combustion efficiency of briquettes. The particle size of the screened sesame stalk for each sieved sample was determined using the average of the particle size on the upper and lower sieve.

Briquetting of sesame stalk would be useful for making fuel briquette with the available cheap binding material of waste paper. The amount of waste paper that is generated each day is a threat to the environment in the world. It is very important to find ways to convert this waste product to use it as a binding agent for fuel briquette in order to alleviate these problems. Mixing waste paper with sesame stalk could result in better briquette quality and low cost making this fuel more attractive for producers and users alike. It can be used as an additive for solid briquettes instead of burning this waste. Five percentages of waste paper, 10%, 20%, 30%, 40% and 50% are rated on a dry weight basis. Collect, cut, test, and soak the waste paper with water until it looks like fibers. The raw and broken sesame stalk and the binding agent are shown in Fig. 2.

Moisture content is one of the factors affecting briquette production[9]. Percentage Moisture Content of each sample was found using oven drier. That is drying in the oven at 105$^0$C for 12 hours until the mass of the sample was constant and take a mass difference before and after drying to the mass before drying. Therefore the moisture content of the sample was calculated using equation (1).

$$\mathbf{MC\%} = \frac{(\mathbf{mi-mf})}{\mathbf{mi}} * \mathbf{100} \qquad (1)$$

Where: MC% moisture content of the sample, mi is the initial mass of sample and mf is the final mass of sample after oven drying.

**Table 1 Average particle size of screened sesame stalk labeled as A, B, and C.**

| Sesame stalk | The size of the upper sieve(mm) | The sieve of the lower sieve(mm) | Average particle size(mm) |
|---|---|---|---|
| A | 2 | 0(pan) | 1 |
| B | 4 | 2 | 3 |
| C | 6 | 4 | 5 |

**Process description of Briquette production from sesame stalk**

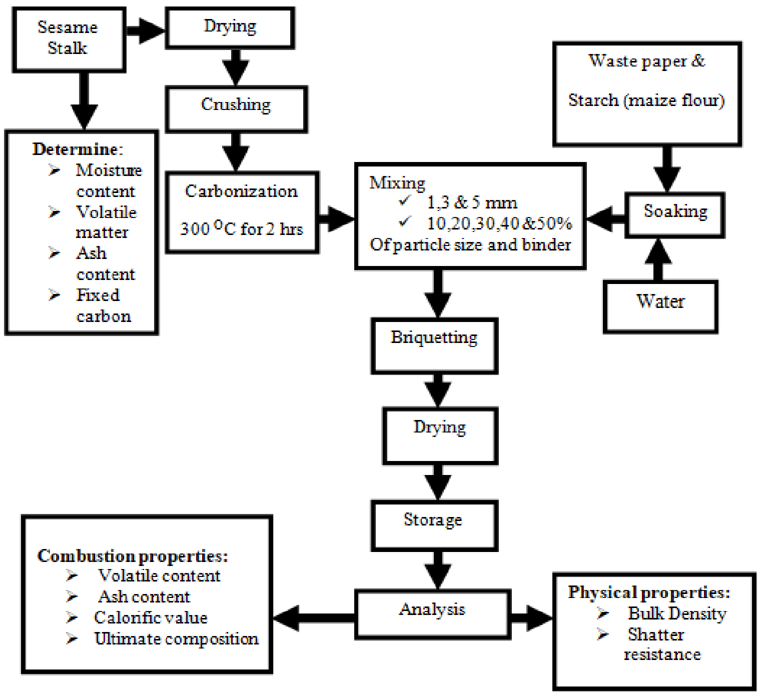


**Figure 1General framework of the experiment**


**Figure 2 Raw material and binding agent**

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**Figure 3 Carbonization of sesame stalk**

### 2.1.1 The percentage ash content

Ash is the non-combustible inorganic residue that remains after complete combustion. A sample of the sesame stalk was placed in an oven until a constant weight was obtained. The oven dried sample was then transferred into the furnace set at a temperature of 900$^0$C and left for about 30 minutes. Then after, the crucible and its contents were transferred to desiccators and then crucible and its contents were reweighed to obtain the weight of ash. The percentage ash content was calculated as the ratio of the weight of ash to that of the weight of the dry sample and was determined using equation (2):

$$AC\% = \frac{W2}{W1} * 100 \quad (2)$$

Where, W1 = Initial weight of oven dried sample (g), W2 = weight of ash (g) and AC (%) = percentage ash content.

### 2.1.2 Percentage volatile matter

The percentage volatile matter (VM %) was determined by weighing of the dried sesame stalk sample in a crucible and placing it in an oven until a constant weight was obtained. The sample was then kept in a furnace at a temperature of 550°C for 10min and weighed after cooling in a desiccator. The percentage volatile matter was then calculated using equation (3):

$$VM\% = \frac{Mi - Mf}{Mi} * 100 \quad (3)$$

Where VM% is the percentage volatile matter, Mi is the weight of the oven-dried sample and Mf is the weight of the sample after 10 min in the furnace at 550$^o$C.

### 2.1.3 Percentage fixed carbon

In high-temperature carbonization, practically all the volatile matter is driven off as gases or liquids, leaving behind a residue that consists principally of carbon with minor amounts of hydrogen, nitrogen, sulfur, and oxygen (which together constitute the fixed-carbon content of the sesame stalk).The amount of fixed carbon can be found by using equation 4.

$$\text{Fixed Carbon} = 100\% - (VM\% + AC\% + MC\%) \quad (4)$$

### 2.1.4 Preparation of carbonized sesame stalk

The dried samples (sesame stalks) were grinded and sieved by standard mesh sizes to less than 5mm particle size. The sesame stalk was labeled as 1mm, 3mm and 5mm which were considered for briquetting purpose to see the effect of particle size on the quality of briquettes. The carbonization process was done at 300$^o$C for 2 hours using the furnace and it has also an impact if it is not properly carried out[10].

### 2.1.5 Determination of physical and combustion properties of sesame stalk briquettes

These characterizations were carried out to find out bulk density, shatter resistance, volatile matter, ash content, ultimate composition and calorific value of the sesame stalk briquettes.

***Bulk density***

The bulk density analysis was performed in order to check the physical properties of the briquette. The produced briquettes were cylindrical in shape, whose volume was known by the formula $\pi/4*D^2*$height. $D=d_1-d_2$ Where $d_1$= outer diameter of briquette, $d_2$=inner hole diameter of briquette or the opening of the briquette and D=diameter of cylindrical briquette. Then bulk density can be calculated by using the formula:

Bulk Density = (mass of briquette) / (volume of briquette) (5)

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### *Shatter resistance*

Measurements were carried out at different particle size and binder percentage to investigate the shatter resistance. Each briquette sample was allowed to drop from a height of 3m onto a concrete floor one times. The durability (%) can be experimentally calculated using equation 7.

$$WL(\%) = \frac{(W_1 - W_2)}{W_1} * 100 \qquad (6)$$

$$SR\ (\%) = 100 - WL \qquad (7)$$

Where WL (%) = weight loss percentage, W1 =weight of briquette before shattering (g), W2= weight of briquette after shattering (g) and SR (%) =shatter resistance percentage.

### *Calorific value*

Calorific value determines the energy content of a fuel. It is the property of biomass fuel that depends on its chemical composition and moisture content and this can be measured by standard Oxygen Bomb calorimeter.

### *Elemental Analysis (Ultimate composition)*

Elemental analysis of the biomass samples was performed using an elemental analyzer "EA 1112 Flash CHNS-O- analyzer" at Addis Ababa University (AAU) Chemistry department.

## 3. RESULT AND DISCUSSION

### *3.1 Physicochemical properties of sesame stalk*

The overall measurement results of the proximate analysis of the raw sesame stalk were summarized in Table 2. The results show that sesame stalk typically has a high volatile matter content (up to 72.82 percent) signifies easy ignition of the sesame stalk and proportionate increase in flame length[11]. It has been found that the low ash content of sesame stalk indicates that it is suitable for thermal utilization. Higher ash content in a fuel usually leads to lower calorific value[12].This combustion characteristic of sesame stalk is sufficient enough to produce heat and it also compares well with most biomass energy. The average ash content of raw sesame stalk was lower but the problem with this approach is in that it is bulky and short combustion time as compared to briquette. The results show that sesame stalk has low fixed-carbon content; this results a short combustion time of the sesame stalk which therefore requires briquetting of the loosely biomass in order to increase the heating value and combustion time.

### *3.2 Effect of particle size*

Particle size has effect on bulk density of any particular particle[13].

### *3.2.2 Bulk Density*

It has been found that the bulk density decreases as the particle size of sesame stalk becomes larger and the densities for the particle size S1, S2, and S3 at constant binder varied from 529.85 to 534.98 kg/m³. The results showed that the maximum bulk density was 534.98 Kg/m³ at particle size of 1mm. The variation of this result is that a decrease in particle size results in an increase in surface area and an available inter-particle bonding area. Reduction in particle size typically results in an increase in the mechanical strength, this is attributed to a greater packing density after the particle rearrangement and an increase in the surface area available for inter particulate attractions.

Thus, the smaller the particle size, the less the pore spaces, more compacted and more mass of the material per given volume which is good for briquetting. Briquettes produced from particle size S1 (1 mm) are denser than briquettes from other two sizes used in this study. This bulk density of briquette indicates more stable and durable during handling, storage, and long distance transportation. Therefore, from the outcome of the investigation it is possible to use the briquettes produced with small particle size which is important for long combustion efficiency and more stability.

**Table 2 Physicochemical properties of sesame stalk**

| Proximate analysis parameters | Percentage |
|---|---|
| Moisture content | 3.63 |
| Ash content | 6.05 |
| Volatile matter | 72.82 |
| Fixed carbon | 17.50 |

**Table 3. The parameter interaction effect on sesame stalk briquette**

| Exp.No. | Names | BD(Kg/m3) | SR (%) | VM (%) | AC (%) | CV(MJ/Kg) |
|---|---|---|---|---|---|---|
| 1 | B11a | 531.74 | 10.8212 | 67.36 | 12.75 | 27.8979 |
| 2 | B11b | 528.21 | 11.61 | 67.86 | 12.85 | 27.8532 |
| 3 | B12a | 533.76 | 11.26 | 69.21 | 10.38 | 27.8134 |
| 4 | B12b | 524.04 | 11.62 | 66.05 | 10.54 | 27.9894 |
| 5 | B13a | 545.88 | 11.6722 | 69.23 | 10.79 | 28.0124 |
| 6 | B13b | 506.47 | 11.62 | 69.2 | 10.77 | 27.9931 |
| 7 | B21a | 521.54 | 10.381 | 64.47 | 13.35 | 26.3521 |
| 8 | B21b | 542.42 | 11.82 | 64.69 | 13.05 | 26.3559 |
| 9 | B22a | 553.91 | 11.3645 | 66.02 | 12.15 | 26.3589 |
| 10 | B22b | 505.91 | 11.47 | 65.96 | 12.33 | 27.2351 |
| 11 | B23a | 531.6 | 11.6882 | 66.34 | 10.88 | 26.01567 |
| 12 | B23b | 521.58 | 11.55 | 66.27 | 10.98 | 27.8762 |
| 13 | B31a | 545.88 | 11.1694 | 62.93 | 13.65 | 25.3652 |
| 14 | B31b | 524.08 | 10.9807 | 62.54 | 13.15 | 27.07 |
| 15 | B32a | 542.6 | 11.2396 | 63.82 | 12.67 | 26.0256 |
| 16 | B32b | 521.4 | 11.2301 | 63.93 | 12.53 | 26.5888 |
| 17 | B33a | 556.53 | 11.5007 | 64.45 | 11.89 | 25.3864 |
| 18 | B33b | 503.05 | 11.4341 | 64.04 | 11.81 | 27.7178 |
| 19 | B41a | 556.76 | 10.8564 | 60.43 | 13.58 | 26.1235 |
| 20 | B41b | 513.65 | 10.9478 | 59.72 | 14.24 | 25.8865 |
| 21 | B42a | 547.93 | 11.175 | 62.76 | 13.86 | 27.3561 |
| 22 | B42b | 516.24 | 11.1859 | 62.61 | 12.98 | 24.9101 |
| 23 | B43a | 535.43 | 11.4519 | 64.2 | 12.85 | 25.5329 |
| 24 | B43b | 525.2 | 11.41 | 63.8 | 12.09 | 26.4353 |
| 25 | B51a | 550.73 | 10.8579 | 60.86 | 13.98 | 25.3125 |
| 26 | B51b | 520.47 | 11 | 60.71 | 14.52 | 25.0214 |
| 27 | B52a | 557.57 | 11.3053 | 61.43 | 14.65 | 26.0235 |
| 28 | B52b | 507.02 | 10.89 | 61.66 | 13.59 | 25.7763 |
| 29 | B53a | 575.36 | 11.4384 | 62.73 | 13.24 | 25.3128 |
| 30 | B53b | 485.47 | 11.02 | 62.73 | 14.08 | 26.5558 |

B11a (Sample Lavel), BD (Bulk Density), SR (Shatter Resistance), VM (Volatile Matter), AC (Ash Content %), CV (Calorific Value in MJ/Kg)

**Table 4 Physicochemical properties of sesame stalk**

| Sample type | C | H | N | S | O |
|---|---|---|---|---|---|
| **Sample A** | 26.32 | 9.22 | 0.18 | 0.05 | 53.77 |
| **Sample B** | 26.75 | 9.62 | 0.4 | 0.13 | 52.32 |
| **Sample C** | 27.45 | 9.01 | 0.25 | 0.04 | 52.32 |
| **Average** | 26.84 | 9.28 | 0.27 | 0.073 | 52.80 |

Based on the above interaction effect parameter, it has been found that the optimum particle size and waste paper percentage was obtained at the combination of 5mm and 10%. At this interaction the highest calorific value of the briquette obtained. The Volatile matter was increased from 62.74% to 64.25% and decreased bulk density (534.98-529.85 Kg/m3), shatter resistance(89.02-88.55%) ash content (13.40-11.85%) and there was no significant effect on Calorific value which is constant 28.00 MJ/Kg with increasing sesame stalk particle size from 1mm to 5mm at 30% binder. Decreased volatile matter (67.63-61.55%), calorific value (27.90-25.89MJ/Kg) and increased ash content (10.46-14.12%), bulk density (528.98-532.32 Kg/m3) and shatter resistance (88.56-88.9%) with increasing waste paper percentage from 10% to 50% at 3mm particle size. Therefore, from the experiment has been found that the optimum value of the parameter of particle size and waste paper percentage was obtained at the combination of 5 mm and 10% with optimal values volatile matter of 69.20%, ash content of 10.78% and gross calorific value of 28.00MJ/Kg as shown on Table 3.

### *3.2.3 Elemental analysis*

Based on the elemental analysis of briquette composition shown on Table 4 the results of the physical chemical property of sesame stalk briquette in terms of combustibility were found to be satisfactory.

During analysis of parameter effect on briquette production the result showed that no significant difference ($p>0.05$) in the bulk density, and calorific value of briquettes with different average particle size except for percentage volatile matter, shatter resistance and ash content. It was also obtained the effect of waste paper percentage was significant ($p<0.05$) on bulk density, shatter resistance, percentage volatile matter, percentage ash content and calorific value of briquettes.

## 4. CONCLUSION

The replacement of petcoke by sesame stalk using waste paper as a binding agent is very important to save the environment from pollution. When this replacement carried out harmful gases such as $CO_2$ can be reduced. Due to the replacement of petcoke by sesame stalk about as an example 2,410 tons of $CO_2$ per year will be reduced from emission. There for it can be concluded that the replacement of petcoke by sesame stalk briquette is very necessary and environmental friendly.

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